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Chugging in patients on veno-venous extracorporeal membrane oxygenation: An under-recognized driver of intravenous fluid administration in patients with acute respiratory distress syndrome?



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ABSTRACT

Background: Veno-venous extracorporeal membrane oxygenation (VV-ECMO) is increasingly utilized in the management of severe acute respiratory distress syndrome (ARDS). Providers who care for patients on VV-ECMO should be familiar with common circuit complications.

Objectives: To provide an example of a common complication, circuit “chugging,” and suggest a management algorithm which aims to avoid excessive fluid administration to patients with ARDS.

Methods: We use a clinical case to illustrate chugging and discuss potential management strategies.

Results: Our patient received frequent boluses of albumin for intermittent circuit chugging contributing to a net positive fluid balance of roughly 6 liters 4 days after cannulation.

Conclusions: Chugging is a common complication for patients on VV ECMO. A thoughtful approach to management may help limit potentially harmful fluid administration for patients with ARDS.

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Introduction

The use of veno-venous extracorporeal membrane oxygenation (VV ECMO) for refractory hypoxemia has dramatically increased in recent years.¹ Providers who care for patients supported with VV ECMO should be familiar with common circuit complications. Additionally, as more patients with severe acute respiratory distress syndrome (ARDS) are placed on VV ECMO, it is important to consider how interventions used to address circuit complications may uniquely impact patients with lung injury. Here, we use a clinical case to illustrate a common complication, circuit “chugging,” and suggest a management algorithm which aims to avoid excessive volume administration to patients with ARDS. Patient data was

obtained as part of a study protocol approved by the Northwestern University Institutional Review Board.

Case

A 37-year-old female with severe idiopathic ARDS was placed on VV ECMO using a 25-French right femoral vein drainage cannula and an 18-French right internal jugular vein outflow cannula (Figures 1 and 2). Cannula size was chosen based on caliber of the vein determined using venous doppler at the time of insertion and body surface area of the patient. She did not have evidence of congestive heart failure on physical exam and a transthoracic echocardiogram obtained on the day of cannulation demonstrated a hyperdynamic left ventricle without wall motion abnormalities and normal right ventricular function. She was mechanically ventilated using the assist control-pressure control mode with 10 cmH₂O of positive end-expiratory pressure and 15 cmH₂O of inspiratory pressure support with resulting tidal volumes of roughly 150 mLs. The fraction of inspired oxygen was set at 0.4. Blood flow through the ECMO circuit was initially 5 liters per minute (LPM) with a pump speed of 4000 rotations per minute (RPM). The following morning, flow through the circuit gradually decreased to 4 LPM despite an increase in pump speed to 4500 RPM. This change was accompanied by visible shaking of the pre-pump venous outflow

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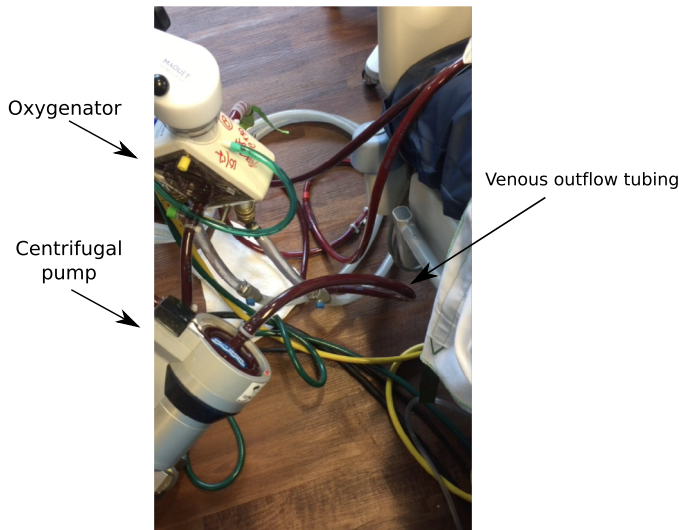


Fig. 1. Veno-venous extracorporeal membrane oxygenation configuration. Chugging occurs in the venous outflow tubing which delivers venous blood to the centrifugal pump. The membrane oxygenator is also labeled.

tubing (Video 1). Mean arterial pressure at the time of the event was 75 mmHg. The patient was receiving systemic anticoagulation and no clots were seen in the membrane oxygenator. Circuit flow improved after the administration of intravenous albumin and a decrease in pump speed to 4000 RPM. Over the next several days,

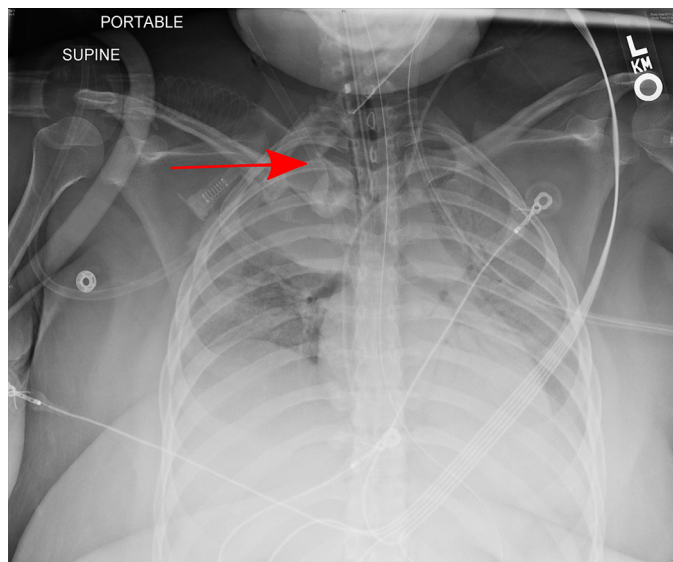


Fig. 2. Anterior-posterior chest radiograph obtained following cannulation for veno-venous extracorporeal membrane oxygenation showing bilateral airspace disease with dense consolidation in the right upper lobe. The outflow cannula can be seen in the right internal jugular vein (red arrow). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1

Daily albumin administration for episodes of chugging and daily net fluid balance

Days after VV ECMO cannulation	Daily albumin boluses for chugging (total grams administered)	Daily fluid balance (liters)
0	5 (62.5)	−0.85
1	5 (62.5)	+2.0
2	5 (62.5)	+2.4
3	6 (100)	+1.4
4	6 (87.5)	+1.2

the patient received frequent boluses of albumin for intermittent circuit chugging contributing to a net positive fluid balance of roughly 6 liters 4 days after cannulation (Table 1). Despite prolonged ECMO support, the patient's lung function failed to improve and she ultimately expired.

Discussion

Contemporary ECMO devices use a centrifugal pump to generate a pressure gradient between the patient's venous circulation and the ECMO circuit which drives blood flow. In settings of low central venous pressure or high pump speed, the negative pressure generated by the pump may cause venous collapse and a temporary decrease in blood flow. This can be visualized at the bedside as "chugging" (also referred to as "chatter") – rhythmic pulsations of the ECMO tubing due to erratic flow. If left untreated, this may progress to fluctuations in the measured ECMO flows or complete flow cessation due to "suck-down."

Despite the frequency of this complication, the clinical implications of chugging are unknown and there is no data to guide optimal management.¹ The most concerning potential consequence of chugging is progressive hypoxemia due to decreased flow through the ECMO circuit. Patients with severe ARDS who require high levels of ECMO support may be particularly sensitive to even small decrements in circuit flow. Additionally, excessive negative pressure in the drainage cannula may directly injure red blood cells. Monitoring levels of lactate dehydrogenase and serum free hemoglobin may help identify chugging-related hemolysis although there is not consensus on when or how often these values should be checked.

Hypovolemia is frequently mentioned as a leading cause of circuit chugging.² As a result, chugging is often reflexively "treated" with repeated boluses of intravenous fluid. Our case illustrates how this may contribute to a net positive fluid balance for patients with ARDS. Given the known benefits of a conservative fluid strategy in ARDS and the association between a positive fluid balance and mortality for patients on VV ECMO, a more nuanced approach to chugging is recommended.^{3,4}

Figure 3 outlines a suggested management algorithm for chugging that aims to limit fluid administration to patients with ARDS. Clinicians should first confirm that chugging is occurring in the pre-pump drainage tubing. Chugging isolated to the post-pump tubing is not uncommon and may result from blood flow at high velocities within the tubing. Hence, post-pump chugging alone may not reflect hypovolemia. If available, monitoring pressure in the venous



Fig. 3. Suggested management algorithm for patients with chugging.

drainage cannula may aid in the early detection of chugging. Pressures less than -100 mmHg are typically viewed as an indication of impaired venous drainage warranting intervention. Second, in the setting of severe volume depletion or shock, intravenous fluids should be administered to increase intravascular volume. Signs of volume depletion may include low mean arterial and central venous pressures, elevated lactic acid levels, and (if kidney function is intact) low urine output. The type of fluids administered should be tailored to the clinical scenario. Blood products should be given if there is evidence of anemia and/or bleeding. Otherwise, discrete boluses of colloid or crystalloid should be provided monitoring closely for clinical response. While colloid solutions like albumin have been theorized to be more effective in increasing intravascular volume, a clear benefit over crystalloid solutions has not been established in clinical trials.⁵ For patients without clinical evidence of hypovolemia, reflexive fluid administration should be avoided. Third, the pump speed should be decreased. The resulting decrease in non-laminar flow may paradoxically improve overall flow through the circuit. Oxygenation should be closely monitored while decreasing pump speed. If chugging persists, correct cannula position should be confirmed and the circuit inspected for any evidence of thrombus which is most commonly identified on the membrane oxygenator. If the above conservative maneuvers have failed, a second drainage cannula can be added to achieve the same flow rate with less negative pressure.

In conclusion, chugging is a common complication for patients on VV ECMO. A thoughtful approach to management may help limit potentially harmful fluid administration for patients with ARDS.

Supplementary Data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.hrtlng.2018.03.011>.

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